SHOOT DENSITY AND LEAF REMOVAL EFFECTS ON MICROCLIMATE, YIELD, FRUIT COMPOSITION AND WINE QUALITY OF THE PORTUGUESE VINE VARIETY 'TOURIGA NACIONAL'

INFLUENCE DE LA DENSITE DE VEGETATION ET DE L'EFFEUILLAGE SUR LE MICROCLIMAT, RENDEMENT, COMPOSITION DU BAIE ET QUALITE DU VIN DU CEPAGE PORTUGAIS 'TOURIGA NACIONAL'

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Abstract:
The objectives of this experiment were to evaluate the influence of shoot density and basal leaf removal on the canopy microclimate characteristics and their influence on yield, fruit composition and wine quality of one of the most important and noble Portuguese red vine varieties – Touriga Nacional.
The experiment was carried out in 2004 on a private enterprise (Dão Sul, Soc. Vitivinícola, SA) of Dão region, centre of Portugal. The vineyard was grafted in 1991 on 1103 P rootstock. The training system is Royat bilateral with vertical shoot positioning. Three different shoot densities were applied: D1 – 23 shoots/m row, D2 – 17 shoots/m row and D3 – 11 shoots/m row. At veraison was also introduced another factor: leaf removal (under clusters).
During the growing season several parameters were measured (leaf area, leaf water potential, leaf gas-exchanges, leaf layer number, canopy size, intercepted photosynthetically active radiation, fruit composition, yield and vigour).
Basal leaf removal improved the canopy microclimate by a lower leaf layer number with positive effects on the interception of radiation at fruit zone, inferior percentage of interior leaves and clusters. On shoot density, it was verified that the D2 presented the best conditions of canopy microclimate.
Yield was positively influenced by shoot density increase by the augment of the cluster number, while cluster weight was not affected. Leaf removal had not a significant effect on yield parameters.
The lower shoot density (D3) improved wine quality by greater colour intensity. Leaf removal improved significantly the wines colour intensity.

Key words – shoot density, leaf removal, canopy microclimate, yield and wine quality.

Resume:
Les objectifs de ce travail ont été l'évaluation de l'influence de la densité des sarments et de l'effeuillage sur les caractéristiques du microclimat de la végétation et son influence sur le rendement, la composition du baie et la qualité du vin du cépage 'Touriga Nacional', un des plus importants et nobles de la viticulture portugaise. L'étude a été effectuée pendant l'année 2004 dans une entreprise privée (Dão Sul, Soc. Vitivinícola, SA) en région D.O.C. Dão, au centre nord du Portugal. Le vignoble de 13 ans a été greffé sur 1103 P. Le système de conduite est le Royat bilatéral, palissé verticalement. Trois différents densités de sarments ont été applis: D1 – 23 sarments/m ligne, D2 – 17 sarments/m ligne et D3 – 11 sarments/m ligne. A la véraison, l'effeuillage a été effectué au dessous des grappes.

Au cours de la saison on a mesuré diverses paramètres (surface foliaire totale, potentiel hydrique foliaire, échanges gazeux au niveau des stomates, nombre de couches de feuilles, dimensions de la végétation, microclimat lumineux, composition de la baie, rendement et vigueur).
L’effeuillage a améliore le microclimat du couvert végétal lumineux par la réduction du nombre de couches de feuilles avec des effets positives sur l’interception de la radiation dans la zone fructifère et inférieur pourcentage de feuilles et grappes intérieures. La densité des sarments D2 a présenté le meilleur microclimat lumineux.
Le rendement a augmenté avec l’augmentation de la densité de sarments a cause du plus grand nombre de grappes. L’effeuillage n’a pas influencé les paramètres de la production.
La moindre densité de sarments (D3) a amélioré la qualité du vin au niveau de l’intensité colorante. L’effeuillage a augmenté significativement la coloration des vins.

Mots - clé – densité de la végétation, effeuillage, microclimat de la végétation, rendement et qualité du vin.

1. INTRODUCTION

Canopy management techniques are the ensemble of the operations executed over the herbaceous organs of grapevine able to modify their number, weight, surface and position. This kind of interventions are interesting in vines with excessive vigour, in which, using adequate interventions we can increase wine’s quality (Smart & Robinson, 1991).
A combination of improved cultivation techniques, fertilizers and pesticides, has resulted in the establishment of some excessively vigorous vineyards in some regions. Shoot crowding and non-uniform leaf area distribution are persistent problems in vigorous vineyards and result in the rapid envelopment of fruits by a wall of foliage (Percival *et al.*, 1994).
Three principal means of microclimate manipulation are covered: shoot number control, vigour control and the use of trellis systems (Smart & Robinson, 1991).
The leaf removal is one of the most common canopy management operations and it consists in the removal of a variable number of leaves in the fruit zone improving the aeration and the exposition of clusters, prevention of cryptogrammic diseases and facilitating the harvest (Smart & Robinson, 1991).
The other canopy management technique that will also be studied is shoot density correction which, despite not being so used, is also important because it will influence in a direct form the canopy density, modifying its microclimate conditions (Figueira, 2005).

2. MATERIAL AND METHODS

The experimental trial was conducted in 2004, in a vineyard situated in Carregal do Sal (40º26’N, 1º6’W), in the Dão’s demarcated region in a private company (Dão Sul, Soc. Vitivinícola, SA), with ‘Touriga Nacional’ vine variety grafted in 1990 onto rootstock 1103 P. The vineyard has a slightly southern exposure and row orientation is North-South.
Vines were planted (2,5 x 1,2m spacing) and trained onto a Royat bilateral with vertical shoot positioning. The soil is, according to FAO’s classification, a Cambisoil, that has a granitic origin, franc-sandy, acid and with a low hydric reserve.
The vine variety ‘Touriga Nacional’ is considered one of most nobles’ varieties of Portugal and also one of the oldest in Douro and Dão’s regions, from where it is originary. It is characterized by a downward position, a high potential fertility, but with a medium to low productivity, due to high levels of coulure, which has motivated the disinterest for its plantation.
According to hydric balance of Thornthwaite, this region’s climate is mesothermic, with little or no thermal efficiency in the summer, sub-damp to dry with moderate water superavit in the winter and moderate deficit in the summer (B’3 a C1s).
Leaf gas-exchanges were measured with a portable IRGA system (ADC-LCA4 model) and leaf water potential with a pressure chamber (Scholander type). Diurnal courses of leaf water potential (Ψ) and photosynthesis (A) were measured throughout the growing season. In each

day, both Ψ and leaf gas-exchanges were measured at predawn and thereafter 3 times a day (10 am, 2 and 6 pm) along the season. Measurements were made on six leaves per treatment. Leaf area was determined with the method propose by Lopes & Pinto (2001). The canopy structure was evaluated by Point Quadrat method (Smart & Robinson, 1991), and there were made 45 insertions (in both canopy levels) in each treatment.
A 'split-plot' experiment was designed with 3 replications with 90 vines per treatment.

3. RESULTS AND DISCUSSION

3.1 Canopy structure

We verified that the canopy width in the fruit zone was lower in D2, while D3 showed higher values of top canopy width, due to the greater development of laterals (table 1 and figure 1).
The greatest effect of leaf removal was the reduction observed in the canopy height and in the fruit zone canopy width.
The exposed leaf surface presents similar values for the three shoot densities. In the D1 and D3 without defoliation treatments the exposed leaf surface reach values close to 12.000 m^2/ha which are desirable values, taking into account the interlines spacing. However in every treatment this parameter presents lower values than those that are considered optimal by Smart & Robinson (1991) who appoint to values near 21.000 m^2/ha. The defoliation, like expected, reduced the exposed leaf surface and originated values lower than 10.000 m^2/ha, in D1 and D2 treatments.
The leaf layer number (LLN) in the fruit zone was reduced to half by leaf removal, and this treatment originated a LLN near 1, which is a lower value than the one that Castro (1997) considered optimal for Dão's region: 3. During the ripening, this parameter has been reduced in all densities especially in D2, which was due to leaf senescence and an attack of *Empoasca vitis*, more evident in this treatment (table 1)

Table 1 *– Shoot density and basal leaf removal influence on canopy structure at ripening. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2- 17 shoots/m row; D3 – 11 shoots/m row. F0 – control; F1 – basal leaf removal.*

Tableau 1 *– Influence de la densité de sarments et de l'effeuillage sur la structure du couvert végétal pendant la maturation. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2- 17 sarments/m ligne; D3 – 11 sarments/m ligne. F0 – témoin; F1 – effeuillage.*

	Canopy height (cm)	**Fruit zone width (cm)**	**Vegetative width (cm)**	**Exposable Surface Area - ESA (m^2/ha)**	**LLN**	**LA/ fruit (cm^2/g)**
D1/F0	128 a	48 ab	40 ab	11876 a	3.1 a	27,2
D1/F1	98 c	45 bc	41 a	9468 c	0.9 c	26,3
D2/F0	121 a	43 cd	41 ab	11276 ab	2.4 b	20,1
D2/F1	102 c	39 d	37 b	9605 c	1.0 c	15,7
D3/F0	126 a	51 a	44 a	11858 a	2.8 ab	30,7
D3/F1	112 b	40 d	43 a	10613 bc	1.3 c	*24,9*
Sig.	**	*	*	*	*	*na*

Note: *Sig*.- signification level; ns- non significant; *- significant with $p < 0,05$; ** - significant with $p < 0,01$; *** - significant with $p < 0,001$.

The interception of PAR at the fruit zone was particularly enhanced by basal leaf removal (F1). In what concerns to shoot density, the leaf senescence and an attack of *Empoasca vitis*, improved the light microclimate at medium density (D2 – figure 1).

The average leaf area per shoot is strongly influenced by shoot density, being the density D3 the one which conduced to a higher leaf surface for shoot, due to its high laterals development (figure 2).

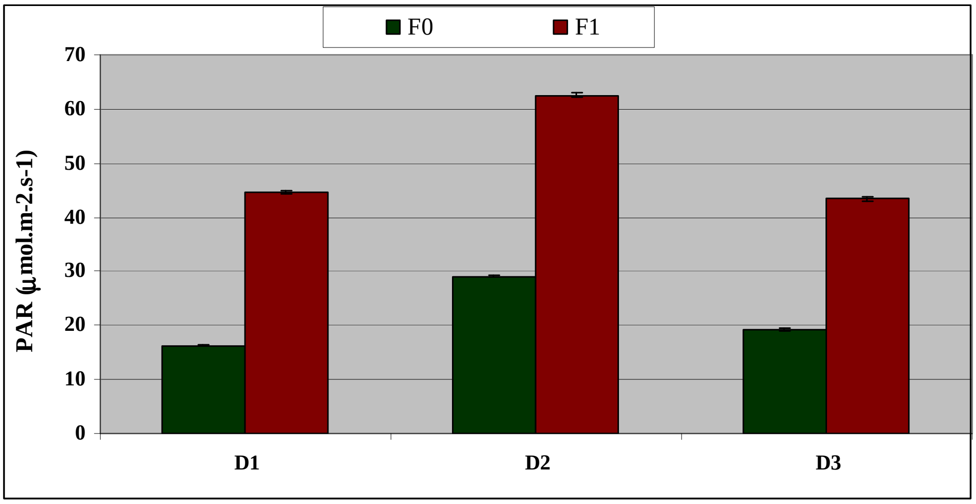

***Figure 1** – Shoot density and basal leaf removal influence on interception of PAR at fruit zone at ripening. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2- 17 shoots/m row; D3 – 11 shoots/m row. F0 – control; F1 – basal leaf removal.*

***Figure 1** – Influence de la densité de sarments et de l'effeuillage sur la interception de la PAR pendant la maturation. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2- 17 sarments/m ligne; D3 – 11 sarments/m ligne. F0 – témoin; F1 – effeuillage.*

The index that represents the leaf area necessary to ripe one gram of grape was higher, than the values, of 6 to 17 cm2/g, that are considered most favourable for a high quality harvest by Williams *et al.* (1987), in D3 and D1, but D2 had values close to optimal. Defoliation has reduced the value of this parameter, in every density.

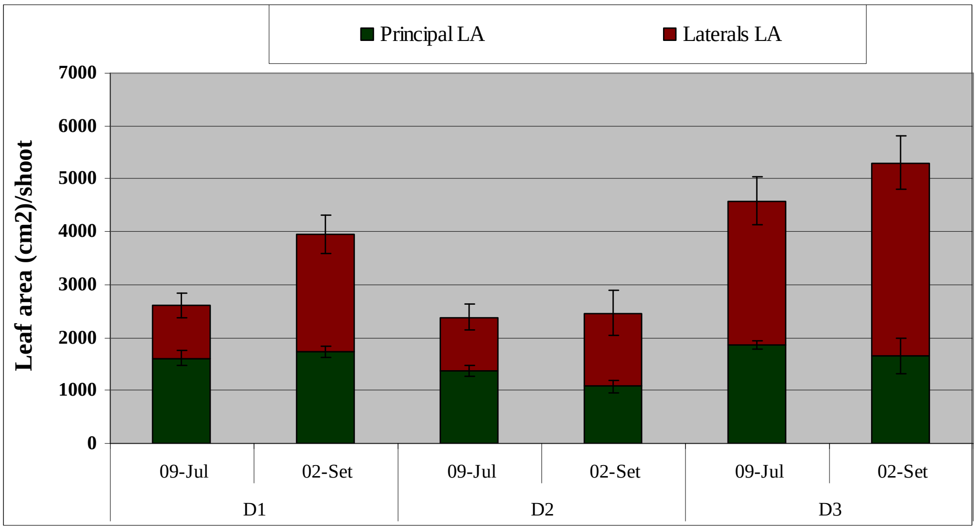

***Figure 2** – Shoot density and basal leaf removal influence on leaf area per shoot. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2- 17 shoots/m row; D3 – 11 shoots/m row. F0 – control; F1 – basal leaf removal.*

***Figure 2** – Influence de la densité de sarments et de l'effeuillage sur la surface foliaire par sarment. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2- 17 sarments/m ligne F0 – témoin; F1 – effeuillage.*

3.2 Ecophysiological behaviour

The predawn leaf water potential stood always at high levels as result of good water availability in soil. The higher value was reached at the end of August (-0.02 MPa) because of an atypical rainy month of August. In the other side, the lower value (-0.3 MPa) happened at the end of September, by the time of harvest, and it has been originated by a hot and dry September's month (figure 3).

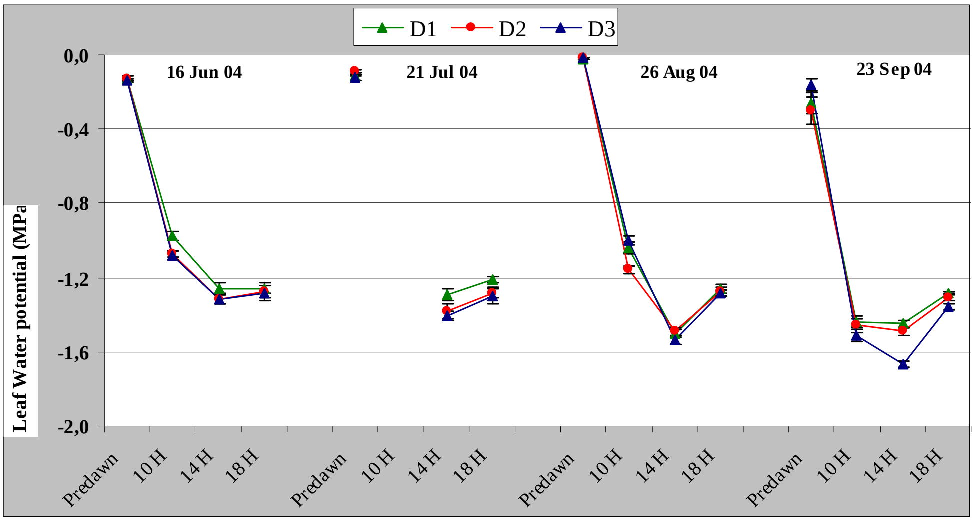

***Figure 3** – Shoot density influence on diurnal and seasonal evolution of leaf water potential. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2- 17 shoots/m row; D3 – 11 shoots/m row.*

***Figure 3** – Influence de la densité de sarments sur l'évolution journalière et sazonal du potentiel hydrique foliaire. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2- 17 sarments/m ligne; D3 – 11 sarments/m ligne.*

The photosynthetic rate remained mostly at high levels all over the season (figure 4).

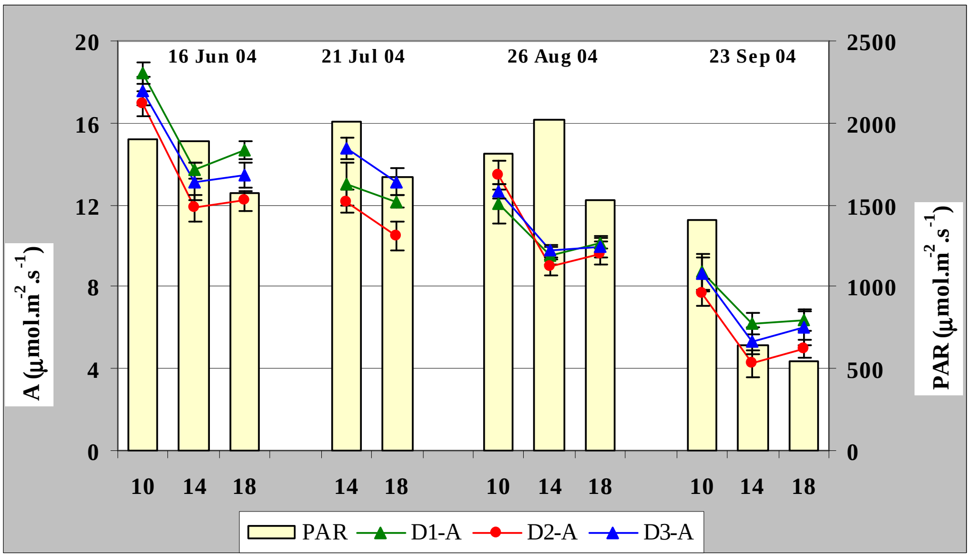

***Figure 4** – Shoot density influence on diurnal and seasonal evolution of Photosynthetic rate. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2- 17 shoots/m row; D3 – 11 shoots/m row.*

***Figure 4** – Influence de la densité de sarments sur l'évolution journalière et sazonal du potentiel hydrique foliaire. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2- 17 sarments/m ligne; D3 – 11 sarments/m ligne.*

3.2 Yield components

Cluster number per vine was strongly affected by shoot density and we verified that higher densities conduced to higher yield, because the shoot suppression reduced the inflorescence number (table 2). This situation has also been reported by Reynolds *et al*. (1994). Unlike what these authors referred, we have not found significant differences in cluster's weight.

Table 2 – Shoot density and basal leaf removal influence on yield components. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2- 17 shoots/m row; D3 – 11 shoots/m row. F0 – control; F1 – basal leaf removal.

Tableau 2 – Influence de la densité de sarments et de l'effeuillage sur le rendement. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2- 17 sarments/m ligne; D3 – 11 sarments/m ligne. F0 – témoin; F1 – effeuillage.

	Nº Cluster/vine	**Cluster weight (g)**	**Yield (t/ha)**
D1/F0	46,2 a	88,3	13,3 a
D1/F1	44,5 a	87,1	12,8 a
D2/F0	36,5 b	92,2	11,3 a
D2/F1	36,7 b	93,9	11,4 a
D3/F0	30,1 c	91,6	9,0 b
D3/F1	26,1 c	90,1	7,9 b
Sig.	*	n.s.	*

Note: *Sig*.- signification level; ns- non significant; *- significant with p < 0,05; ** - significant with p < 0,01; *** - significant with p < 0,001.

However D3 in spite of be the least productive, have still a good (medium) production for this vine variety. Defoliation had no effects on yield components, as has been referred by Percival *et al*. (1994), Afonso *et al*. (1997).

3.3 Must and wine quality

The grapes characteristics at harvest were not influenced by both treatments.

However wine's quality was affected in what concerns colour intensity. We can see that higher shoot densities reduced colour intensity unlike leaf removal that improved this parameter, as reaction of greater anthocyanin content (table 3).

Table 3 – Shoot density and basal leaf removal influence on must and wine quality. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2-17 shoots/m row; D3–11 shoots/m row. F0–control; F1–basal leaf removal.

Tableau 3 – Influence de la densité de sarments et de l'effeuillage sur la qualité du moût et du vin. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2-17 sarments/m ligne; D3–11 sarments/m ligne. F0–témoin; F1–effeuillage.

	Probable Alchoolic Degree (% v/v)	**Berry Weight (g)**	**Total Acidity (g tart. ac./l)**	**pH**		**Wine Colour Intensity**
D1/F0	14,6	1,85	6,62	3,52		4,6 c
D1/F1	15,8	1,86	6,62	3,56		4,8 bc
D2/F0	15,3	1,75	6,62	3,56		5,2 bc
D2/F1	14,5	1,75	6,50	3,58		5,4 b
D3/F0	15,1	1,77	6,62	3,57		5,3 bc
D3/F1	15,3	1,83	6,75	3,55		6,5 a
Sig.	n.s.	n.s.	n.s.	n.s.		*

Note: *Sig*.- signification level; ns- non significant; *- significant with p < 0,05; ** - significant with p < 0,01; *** - significant with p < 0,001.

3.4 Vegetative expression and vigour

Defoliation usually doesn't affect the vigour parameters, when this operation is realized in a late stage of season. Lateral's number, whether per vine or per shoot, has been increased by the lowest shoot density. The D1 and D3 treatments present the higher values of pruning weight. These results indicate that D3 conduces to an excessive vigour of vines, characterized by few, but heavy shoots, for which contribute the elevated number of laterals. In D1 treatment, the high pruning weight (1,05 Kg/m) is due to the elevated shoot number, although the shoot weight is the lowest of all treatments. The Ravaz index presented a low value (under 5) in all treatments, particularly due to the characteristic great vigour of this vine variety and not due to a low production (table 4).

Table 4 – Shoot density and basal leaf removal influence on vegetative expression and vigour. 'Touriga Nacional' vine variety. D1-23 shoots/m row; D2-17 shoots/m row; D3–11 shoots/m row. F0 – control; F1 – basal leaf removal.

Tableau 4 – Influence de la densité de sarments et de l'effeuillage sur la expression végétatif el sur la vigueur. Cépage 'Touriga Nacional'. D1-23 sarments/m ligne; D2-17 sarments/m ligne; D3–11 sarments/m ligne. F0 – témoin; F1 – effeuillage.

	Laterals nº/shoot	Shoot nº/vine	Average shoot weight (g)	Pruning weight		Ravaz Index
				(Kg) /vine	(Kg) /m	
D1	0,7 b	21,2 b	45,1 b	1,26 a	1,05 a	4,1 a
D2	0,8 b	15,8 b	51,4 b	1,06 b	0,88 b	4,1 a
D3	3,0 a	41,8 a	103,2 a	1,44 a	1,20 a	2,5 b
Sig.	***	***	***	**	**	**

Note: *Sig*.- signification level; ns- non significant; *- significant with $p < 0,05$; ** - significant with $p < 0,01$; *** - significant with $p < 0,001$.

4. CONCLUSIONS

It has been observed that leaf removal strongly reduced the exposed leaf surface, while shoot density had no effects on this parameter. Leaf removal has also improved the clusters zone microclimate, which is proved by the reduction of LLN, of the interior clusters and leaves percentage and by the increase of radiation interception.

The photosynthesis and the leaf water potential have not been affected by leaf removal or by shoot density.

Concerning to yield components, we may conclude that shoot density D1 was the higher productive treatment. It hasn't been noted a significant difference in average cluster weight, however the higher shoot densities have a tendency to lower values.

The vigour parameters analysis showed that every treatment have excessive vigour. The D1 and D3 treatments had the highest pruning weight, while D3 had the highest average shoot weight, essentially due to the large amount of laterals that this treatment had.

There were found slightly, but significant, differences between shoot densities, being the lowest density the one that reached a higher alcoholic degree and colour intensity. Although defoliation hasn't originated significant differences in alcoholic degree, it has improved wines' colour intensity.

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